DIVISION 3

SECTION 3103F – STRUCTURAL LOADING CRITERIA

3103F.1 General. *Section 3103F establishes the environmental and operating loads acting on the Marine Oil Terminal (MOT) structures and on moored vessel(s). The analysis procedures are presented in Sections 3104F – 3107F.*

3103F.2 Dead Loads.

3103F.2.1 General. *Dead loads shall include the weight of the entire structure, including permanent attachments such as loading arms, pipelines, deck crane, fire monitor tower, gangway structure, vapor control equipment and mooring hardware. Units weights specified in subsections 3103F.2.2 may be used for MOT structures if actual weights are not available.*

3103F.2.2 Unit Weights. *The unit weights in Table 31F-3-1 may be used for both existing and new MOTs.*

TABLE 31F-3-1

UNIT WEIGHTS

Material	**Unit Weight** (pcf)*****
Steel or cast steel	*490*
Cast iron	*450*
Aluminum alloys	*175*
Timber (untreated)	*40-50*
Timber (treated)	*45-60*
Concrete, reinforced (normal weight)	*145-160*
Concrete, reinforced (lightweight)	*90-120*
Asphalt paving	*150*

** pounds per cubic foot*

3103F.2.3 Equipment and Piping Area Loads. *The equipment and piping area loads in Table 31F-3-2 may be used, as a minimum, in lieu of detailed as-built data.*

TABLE 31F-3-2

EQUIPMENT AND PIPING AREA LOADS

Location	**Area Loads** (psf)*******
Open areas	*20**
Areas containing equipment and piping	*35***
Trestle roadway	*20**

** Allowance for incidental items such as railings, lighting, miscellaneous equipment, etc.*
*** 35 psf is for miscellaneous general items such as walkways, pipe supports, lighting, and instrumentation. Major equipment weight shall be established and added into this weight for piping manifold, valves, deck crane, fire monitor tower, gangway structure, and similar major equipment.*
**** pounds per square foot*

3103F.3 Live Loads and Buoyancy. *The following vertical live loading shall be considered, where appropriate: uniform loading, truck loading, crane loading and buoyancy. Additionally, MOT specific, non-permanent equipment shall be identified and used in loading computations.*

3103F.4 Earthquake Loads

3103F.4.1 General.. *Earthquake loads are described in terms of Peak Ground Acceleration (PGA), spectral acceleration and earthquake magnitude. The seismic analysis procedures (Tables 31F-4-2, and 31F-4-3) are dependent on the risk classification of Table 31F-4-1.*

3103F.4.2 Design Earthquake Motion Parameters. *The earthquake ground motion parameters of peak ground acceleration, spectral acceleration and earthquake magnitude are modified for site amplification and near fault directivity effects. The resulting values are the Design Peak Ground Acceleration (DPGA), Design Spectral Acceleration (DSA) and Design Earthquake Magnitude (DEM).*

The peak ground and spectral acceleration may be evaluated using:

1. *U.S. Geological Survey (USGS) or California Geological Survey (CGS, formerly the California Division of Mines and Geology (CDMG)) maps as discussed in subsection 3103F.4.2.2,*
2. *A site-specific probabilistic seismic hazard analysis (PSHA) as discussed in subsection 3103F.4.2.3.*
3. *For the Ports of Los Angeles, Long Beach and Port Hueneme, PSHA results are provided in subsection 3103F.4.2.3.*

Unless stated otherwise, the DSA values are for 5 percent damping; values at other levels may be obtained as per subsection 3103F.4.2.9.

The appropriate probability levels associated with DPGA and DSA for different seismic performance levels are provided in Table 31F-4-2. Deterministic earthquake motions, which are used only for comparison to the probabilistic results, are addressed in subsection 3103F.4.2.7.

The evaluation of Design Earthquake Magnitude (DEM), is discussed in subsection 3103F.4.2.8. This parameter is required when acceleration time histories (subsection

3103F.4.2.10) are addressed or if liquefaction potential (subsection 3106F.3) is being evaluated.

3103F.4.2.1 Site Classes. *The following site classes, defined in subsection 3106F.2, shall be used in developing values of DSA and DPGA:*

S_A, S_B, S_C, S_D, S_E, and S_F.

For S_F, a site specific response analysis is required per subsection 3103F.4.2.5.

3103F.4.2.2 Earthquake Motions from USGS Maps. *Earthquake ground motion parameters can be obtained from the Maps 29-32 in the National Earthquake Hazard Reduction Program (NEHRP) design map set discussed in subsection 1.6.1 of [3.1], online at (http://geohazards.cr.usgs.gov/eq/html/canvmap.html) or on CD ROM from the USGS. These are available as peak ground acceleration and spectral acceleration values at 5 percent damping for 10 and 2 percent probability of exceedance in 50 years, which correspond to Average Return Periods (ARPs) of 475 and 2,475 years, respectively. The spectral acceleration values are available for 0.2, and 1.0 second spectral periods. In obtaining peak ground acceleration and spectral acceleration values from the USGS web site, the site location can be specified in terms of site longitude and latitude or the zip code when appropriate. The resulting values of peak ground acceleration and spectral acceleration correspond to surface motions for Site Classification approximately corresponding to the boundary of Site Class S_B and S_C.*

Once peak ground acceleration and spectral acceleration values are obtained for 10 and 2 percent probability of exceedence in 50 years, the corresponding values for other probability levels may be obtained. A procedure is presented in subsection 1.6 of Chapter 1 of [3.1].

3103F.4.2.3 Earthquake Motions from Site-Specific Probabilistic Seismic Hazard Analyses. *Peak ground acceleration and spectral acceleration values can be obtained using site-specific probabilistic seismic hazard analysis (PSHA). In this approach, the seismic sources and their characterization used in the analysis shall be based on the published data from the California Geological Survey, which can be obtained online at the following web site: (http://www.consrv.ca.gov/dmg/rghm/psha/Index.htm) [3.2].*

Appropriate attenuation relationships shall be used to obtain values of peak ground acceleration and spectral acceleration at the ground surface for site conditions corresponding to the boundary of Site Class S_B and S_C, regardless of the actual subsurface conditions at the site. These results shall be compared to those based on the FEMA/USGS maps discussed in subsection 3103F.4.2.2. If the two sets of values are significantly different, a justification for using the characterization chosen shall be provided.

Alternatively, peak ground acceleration and spectral accelerations at the ground surface for the subsurface conditions that actually exist at the site may be directly obtained by using appropriate attenuation relationships in a site-specific PSHA. This approach is not permissible for Site Classes S_E and S_F.

For site-specific PSHA, peak ground acceleration and spectral acceleration values corresponding to the seismic performance level (See Table 31F-4-2) shall be obtained.

For peak ground acceleration, PSHA may be conducted using the "magnitude weighting" procedure in Idriss [3.3]. The actual magnitude weighting values should follow the Southern California Earthquake Center (SCEC) procedures [3.4]. This magnitude weighting procedure incorporates the effects of duration corresponding to various magnitude events in the PSHA results. The resulting peak ground acceleration shall be used only for liquefaction assessment (see subsection 3106F.4).

PSHA have been developed for the Port of Los Angeles, Port of Long Beach and Port Hueneme. This assessment has included a review of onshore and offshore faulting and was performed by Lawrence Livermore National Laboratory [3.5]. Resulting response spectra are provided in Tables 31F-3-3, 31F-3-4 and Figures 31F-3-1 and 31F-3-2. Results are provided only for site classification "S_C" and five percent damping. These spectral values (DSA's) are the minimum acceptable and represent the subsurface only. To obtain appropriate values for piles and/or the mudline, the simplified procedures of subsection 3103F.4.2.4 may be used.

TABLE 31F-3-3
Response Spectra
for the Ports of Los Angeles and Long Beach
475 Year Return Period *(5% Critical Damping)*
Site Class "C"
(Shear Wave Velocity from 1220-2500 ft/sec)

Period *(sec)*	***Frequency*** *(Hz)*	***Spectral Acceleration*** *(g's)*
0.03	33.33	0.47
0.05	20.00	0.52
0.10	10.0	0.71
0.15	6.67	0.86
0.20	5.0	0.93
0.30	3.33	0.93
0.50	2.00	0.85
1.0	1.0	0.62
2.0	0.50	0.37

3103F.4.2.4 Simplified Evaluation of Site Amplification Effects. *When the MOT Site Class is different from the S_B - S_C boundary, site amplification effects shall be incorporated in peak ground accelerations and spectral accelerations. This may be accomplished using a simplified method or a site-specific evaluation (subsection 3103F.4.2.5).*

TABLE 31F-3-4 Response Spectra for Port Hueneme 475 Year Return Period (5% Critical Damping)		
Site Class "C" (Shear Wave Velocity from 1200-2500 ft/sec)		
Period (sec)	**Frequency** (Hz)	**Spectral Acceleration** (g's)
0.03	33.33	0.41
0.05	20.00	0.46
0.10	10.0	0.63
0.15	6.67	0.75
0.20	5.0	0.80
0.30	3.33	0.78
0.50	2.00	0.69
1.0	1.0	0.49
2.0	0.50	0.28

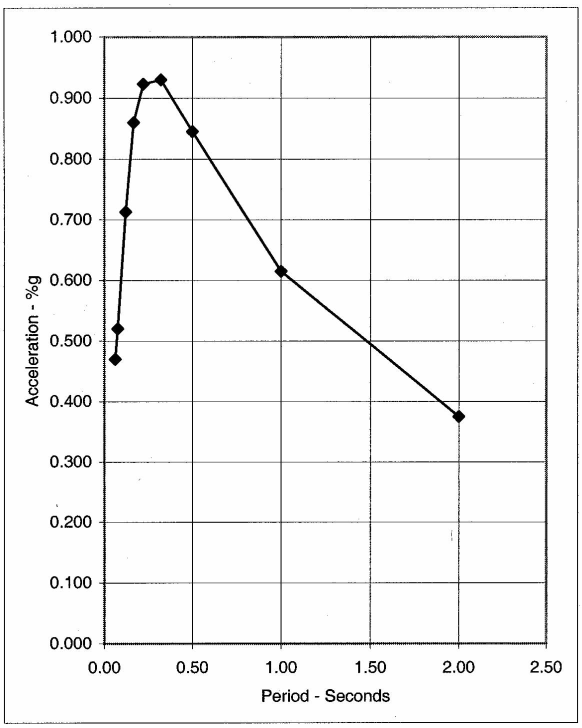

Figure 31F-3-1 Response Spectra for the Ports of Los Angeles and Long Beach, 475 Year Return Period (5% Critical Damping)

For a given Site Class, the following procedure [3.1] presents a simplified method that may be used to incorporate the site amplification effects for peak ground acceleration and spectral acceleration computed for the S_B and S_C boundary.

1. *Calculate the spectral acceleration values at 0.20 and 1.0 second period:*

$$S_{XS} = F_a S_S \quad (3\text{-}1)$$
$$S_{X1} = F_v S_1 \quad (3\text{-}2)$$

Where:

F_a = *site coefficient obtained from Table 31F-3-5*
F_v = *site coefficient obtained from Table 31F-3-6*

S_S = *short period (usually at 0.20 seconds)spectral acceleration value (for the boundary of S_B and S_C) obtained using subsection 3103F.4.2.2, or at the period corresponding to the peak in spectral acceleration values when obtained from subsection 3103F.4.2.3*

S_1 = *spectral acceleration value (for the boundary of S_B and S_C) at 1.0 second period*

S_{XS} = *spectral acceleration value obtained using the short period S_S and factored by Table 31F-3-5 for the Site Class under consideration.*

S_{X1} = *spectral acceleration value obtained using the 1.0 second period S_1 and factored by Table 31F-3-6 for the Site Class under consideration.*

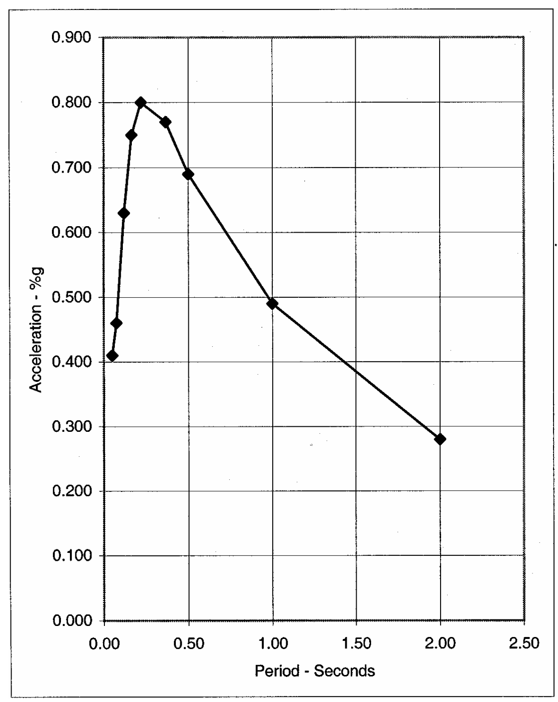

Figure 31F-3-2 Response Spectra for Port Hueneme, 475 Year Return Period (5% Critical Damping)

2. *Set* $PGA_X = 0.4 S_{XS}$ (3-3)

Where:

PGA_X = *peak ground acceleration corresponding to the Site Class under consideration.*

When the value of PGA_X is less than the peak ground acceleration obtained following subsection 3103F.4.2.2 or subsection 3103F.4.2.3, an explanation of the results shall be provided.

TABLE 31F-3-5 **VALUES OF F_a**					
Site Class	S_S				
	<0.25	0.5	0.75	1.0	> 1.25
S_A	0.8	0.8	0.8	0.8	0.8
S_B	1.0	1.0	1.0	1.0	1.0
S_C	1.2	1.2	1.1	1.0	1.0
S_D	1.6	1.4	1.2	1.1	1.0
S_E	2.5	1.7	1.2	0.9	0.9
S_F	*	*	*	*	*
NOTE: Linear interpolation can be used to estimate values of F_a for intermediate values of S_S. * Site-specific dynamic site response analysis shall be performed					

TABLE 31F-3-6 **VALUES OF F_V**					
Site Class	S_1				
	<0.1	0.2	0.3	0.4	>0.5
S_A	0.8	0.8	0.8	0.8	0.8
S_B	1.0	1.0	1.0	1.0	1.0
S_C	1.7	1.6	1.5	1.4	1.3
S_D	2.4	2.0	1.8	1.6	1.5
S_E	3.5	3.2	2.8	2.4	2.4
S_F	*	*	*	*	*
NOTE Linear interpolation can be used to estimate values of F_V for intermediate values of S_1. * Site-specific dynamic site response analysis shall be performed					

3. PGA_X, S_{XS}, and S_{X1} constitute three spectral acceleration values for the Site Class under consideration corresponding to periods of 0, S_S (usually 0.2 seconds), and 1.0 second, respectively.

4. The final response spectra, without consideration for near-fault directivity effects, values of S_a for the Site Class under consideration may be obtained using the following equations (for 5% critical damping):

for $0<T<0.2T_o$

$$S_a = (S_{XS})(0.4 + 3T/T_o) \tag{3-4}$$

where:

T = *Period corresponding to calculated S_a*
T_o = *Period at which the constant acceleration and constant velocity regions of the design spectrum intersect*

for $0.2T_o<T<T_o$

$$S_a = S_{XS} \tag{3-5}$$

for $T>T_o$

$$S_a = S_{X1}/T \tag{3-6}$$

where:

$$T_o = S_{X1}/S_{XS} \tag{3-7}$$

The resulting PGA_X is the DPGA. However, the S_a's (except for the ports of Los Angeles, Long Beach and Port Hueneme) shall be modified for near-fault directivity effects, per subsection 3103F.4.2.6 to obtain the final DSAs.

3103F.4.2.5 Site-Specific Evaluation of Amplification Effects. *As an alternative to the procedure presented in subsection 3103F.4.2.4, a site-specific response analysis may be performed. For S_F, a site specific response analysis is required. The analysis shall be either an equivalent linear or nonlinear analysis. Appropriate acceleration time histories as discussed in subsection 3103F.4.2.10 shall be used.*

In general, an equivalent linear analysis using, for example, SHAKE91 [3.6] is acceptable when the strength and stiffness of soils are unlikely to change significantly during the seismic shaking, and the level of shaking is not large. A nonlinear analysis should be used when the strength and/or stiffness of soils could significantly change during the seismic shaking or significant non-linearity of soils is expected because of high seismic shaking levels.

The choice of the method used in site response analysis shall be justified considering the expected stress-strain behavior of soils under the shaking level considered in the analysis.

Site-specific site response analysis may be performed using one-dimensional analysis. However, to the extent that MOTs often involve slopes or earth retaining structures, the one-dimensional analysis should be used judiciously. When one-dimensional analysis cannot be justified or is not adequate, two-dimensional equivalent linear or nonlinear response analysis shall be performed. Site-specific response analysis results shall be compared to those based on the simplified method of subsection 3103F.4.2.4 for reasonableness.

For the port areas of Los Angeles, Long Beach and Port Hueneme, the resulting response spectra shall not fall below values obtained in subsection 3103F.4.2.3.

The peak ground accelerations obtained from this site-specific evaluation are DPGAs and the spectral accelerations are DSAs as long as the near-fault directivity effects addressed in subsection 3103F.4.2.6 are appropriately incorporated into the time histories (subsection 3103F.4.2.10).

3103F.4.2.6 Directivity Effects. *When the site is 15 km (9.3 miles) or closer to a seismic source that can significantly affect the site, near-fault directivity effects shall* *be reflected in the spectral acceleration values and in the deterministic spectral acceleration values of subsection 3103F.4.2.7. However, Tables 31F-3-3 and 31F-3-4 for the port areas of Los Angeles, Long Beach and Port Hueneme already have these effects included.*

Two methods are available for incorporating directivity effects.

1. *Directivity effects may be reflected in the spectral acceleration values in a deterministic manner by using, for example, the equation on pg. 213 (and Tables 6 and 7) of Somerville, et al. [3.7]. The critical seismic sources and their characterization developed as part of the deterministic ground motion parameters (subsection 3103F.4.2.7) should be used to evaluate the directivity effects. The resulting adjustments in spectral acceleration values may be applied in the probabilistic spectral acceleration values developed per subsection 3103F.4.2.4 or 3103F.4.2.5. Such adjustment can be independent of the probability levels of spectral accelerations.*

2. *Directivity effects may be incorporated in the results of site-specific PSHA per subsection 3103F.4.2.3. In this case, the directivity effects will also depend on the probability level of spectral accelerations.*

If spectral accelerations are obtained in this manner, the effects of site amplification using either subsection 3103F.4.2.4, 3103F.4.2.5 or an equivalent method (if justified) shall be incorporated.

3103F.4.2.7 Deterministic Earthquake Motions. *Deterministic ground motions from "scenario" earthquakes may be used for comparison purposes. Deterministic peak ground accelerations and spectral accelerations may be obtained using the "Critical Seismic Source" with maximum earthquake magnitude and its closest appropriate distance to the MOT. "Critical Seismic Source" is that which results in the largest computed median peak ground acceleration and spectral acceleration values when appropriate attenuation relationships are used. The values obtained from multiple attenuation relationships should be used to calculate the median peak ground acceleration and spectral acceleration values.*
Alternatively, the values of peak ground accelerations and spectral accelerations may be obtained from the USGS maps [3.1], corresponding to the Maximum Considered Earthquake (MCE). In this case, the median values of peak ground acceleration and spectral acceleration values shall be 2/3 (see subsection 1.6 of [3.1]) of the values shown on the USGS maps.

3103F.4.2.8 Design Earthquake Magnitude. *The Design Earthquake Magnitude used in developing site-specific acceleration time histories (subsection 3103F.4.2.10) or liquefaction assessment (subsection 3106F.3) is obtained using either of the following two methods.*

1. *The Design Earthquake may be selected as the largest earthquake magnitude associated with the Critical Seismic Source. The distance shall be taken as the closest distance from the source to the site. The resulting Design Earthquake shall be associated with all DPGA values for the site, irrespective of probability levels.*

2. *The Design Earthquake (DEQ) may be obtained for each DPGA or DSA value and associated probability level by determining the corresponding dominant distance and magnitude. These are the values of the distance and magnitude that contribute the most to the mean seismic hazards estimates for the probability of interest. They are usually determined by locating the summits of the 3-D surface of contribution of each small interval of magnitude and distance to the total mean hazards estimate. If this 3-D surface shows several modes with approximate weight of more than 20% of the total, several DEQs may be considered, and the DEQ leading to the most conservative design parameters shall be used.*

3103F.4.2.9 Design Spectral Acceleration for Various Damping Values. *Design Spectral Acceleration (DSA) values at damping other than 5% shall be obtained by using a procedure given in [3.1], and is denoted as DSA_d. The following procedure does not include near-fault directivity effects.*

For $0 < T < 0.2\,T_o$

$$DSA_d = S_{XS}\ [\,(5/B_S - 2)\ T/\ T_o + 0.4\,] \qquad (3\text{-}8)$$

For $0.2\,T_o < T < T_o$

$$DSA_d = DSA/B_S \qquad (3\text{-}9)$$

For $T > T_o$

$$DSA_d = S_1/(B_1\ T) \qquad (3\text{-}10)$$

where:

T	=	*period*
T_o	=	S_{X1}/S_{XS}
B_S	=	*Coefficient used to adjust the short period spectral response, for the effect of viscous damping.*
B_1	=	*Coefficient used to adjust one-second period spectral response, for the effect of viscous damping*

Values of B_S and B_1 are obtained from Table 31F-3-7.

Such a procedure shall incorporate the near-fault directivity effects when the MOT is 15 km (9.3 miles) or closer to a significant seismic source.

3103F.4.2.10 Development of Acceleration Time Histories. *When acceleration time histories are utilized, target spectral acceleration values shall be initially selected corresponding to the DSA values at appropriate probability levels. For each set of target spectral acceleration values corresponding to one probability level, at least three sets of* *horizontal time histories (one or two horizontal acceleration time histories per set) shall be developed.*

TABLE 31F-3-7 [3.1] *VALUES OF B_S AND B_1*		
Damping (%)	*B_S*	*B_1*
<2	*0.8*	*0.8*
5	*1.0*	*1.0*
10	*1.3*	*1.2*
20	*1.8*	*1.5*
30	*2.3*	*1.7*
40	*2.7*	*1.9*
>50	*3.0*	*2.0*
Note: Linear interpolation should be used for damping values not specifically listed.		

Initial time histories shall consider magnitude, distance, and the type of fault that are reasonably similar to those associated with the conditions contributing most to the probabilistic DSA values. Preferred initial time histories should have their earthquake magnitude and distance to the seismic source similar to the mode-magnitude and mode-distance derived from the PSHA or from appropriate maps. When an adequate number of recorded time histories are not available, acceleration time histories from simulations may be used as supplements.

Scaling or adjustments, either in the frequency domain or in the time domain (preferably), prior to generating acceleration time histories should be kept to a minimum. When the target spectral accelerations include near-fault directivity effects (subsection 3103F.4.2.6), the initial time histories should exhibit directivity effects.

When three sets of time histories are used in the analysis, the envelope of the spectral acceleration values from each time history shall be equal to or higher than the target spectral accelerations. If the envelope values fall below the target values, adjustments shall be made to insure that the spectral acceleration envelope is higher than target spectral accelerations. If the envelope is not higher, then a justification shall be provided.

When seven or more sets of time histories are used, the average of the spectral acceleration values from the set of time histories shall be equal or higher than the target spectral acceleration values. If the average values fall below the target values, adjustments shall be made to insure that average values are higher than the target spectral accelerations. If this is not the case, then an explanation for the use of these particular spectral acceleration values shall be provided.

When three sets of time histories are used in the analysis, the maximum value of each response parameter shall be used in the design, evaluation and rehabilitation. When seven or more sets of time histories are used in the analysis, the average value of each response parameter may be used.

3103F.5 Mooring Loads on Vessels.

3103F.5.1 General. *Forces acting on a moored vessel may be generated by wind, waves, current, tidal variations, tsunamis, seiches and hydrodynamic effects of passing vessels. Forces from wind and current acting directly on the MOT structure (not through the vessel in the form of mooring and/or breasting loads) shall be determined in subsection 3103F.7.*

The vessel's moorings shall be strong enough to hold during all expected conditions of surge, current and weather and long enough to allow adjustment for changes in draft, drift, and tide (2 CCR 2340 (c) (1)) [3.8].

3103F.5.2 Wind Loads. *Wind loads on a vessel, moored at a MOT, shall be determined using procedures described in this subsection. Wind loads shall be calculated for each of the load cases identified in subsection 3105F.2.*

3103F.5.2.1 Design Wind Speed. *The design wind speed is the maximum wind speed of 30-second duration used in the mooring analysis (see Section 3105F).*

3103F.5.2.1.1 Operating Condition. *The operating condition is the wind envelope in which a vessel may conduct transfer operations. It is determined from the mooring analysis (Section 3105F). Transfer operations shall cease, at an existing MOT, when the wind exceeds the maximum velocity of the envelope.*

3103F.5.2.1.2 Survival Condition. *The survival condition is defined as the state wherein a vessel can remain safely moored at the berth during severe winds. For new MOTs, the survival condition threshold is the maximum wind velocity, for a 30 second gust and a 25-year return period, obtained from historical data.*

For an existing MOT, a reduced survival condition threshold is acceptable (see Fig. 2-1). If the wind rises above these levels, the vessel must depart the berth; it shall be able to depart within 30 minutes (see 2 CCR 2340 (c) (28)) [3.8].

The 30-second duration wind speed shall be determined from the annual maximum wind data. Average annual summaries cannot be used. Maximum wind speed data for eight directions (45-degree increments) shall be obtained. If other duration wind data is available, it shall be adjusted to a 30-second duration, in accordance with equation (3.12). The 25-year return period shall be used to establish the design wind speed for each direction. Once these wind speeds are established for each increment, the highest wind speed shall be used to determine the mooring/berthing risk classification, from Table 31F-5-1.
In order to simplify the analysis for barges (or other small vessels), they may be considered to be solid free-standing

walls (Section 6 of ASCE 7-98 [3.9]). This will eliminate the need to perform a computer assisted mooring analysis.

3103F.5.2.2 Wind Speed Corrections. *Wind speed measured at an elevation of 33 feet (10 meters) above the water surface, with duration of 30 seconds shall be used to determine the design wind speed. If these conditions are not met, the following corrections shall be applied.*

The correction for elevation is obtained from the equation:

$$V_w = V_h \left(\frac{33}{h}\right)^{1/7} \qquad (3\text{-}11)$$

where:

V_w = *wind speed at elevation 33 ft. (10 m.)*
V_h = *wind speed at elevation h*
h = *elevation above water surface of wind data[feet]*

The available wind duration shall be adjusted to a 30-second value, using the following formula:

$$V_{t=30\sec} = \frac{v_t}{c_t} \qquad (3\text{-}12)$$

where:

$V_{t=30sec}$ = *wind speed for a 30 second duration*
v_t = *wind speed over a given duration*
c_t = *conversion factor from Figure 31F-3-3*

If wind data is available over land only, the following equation shall be used to convert the wind speed from over-land to over-water conditions [3.10]:

$$V_w = 1.10\ V_L \qquad (3\text{-}13)$$

where:

V_w = *over water wind speed*
V_L = *over land wind speed*

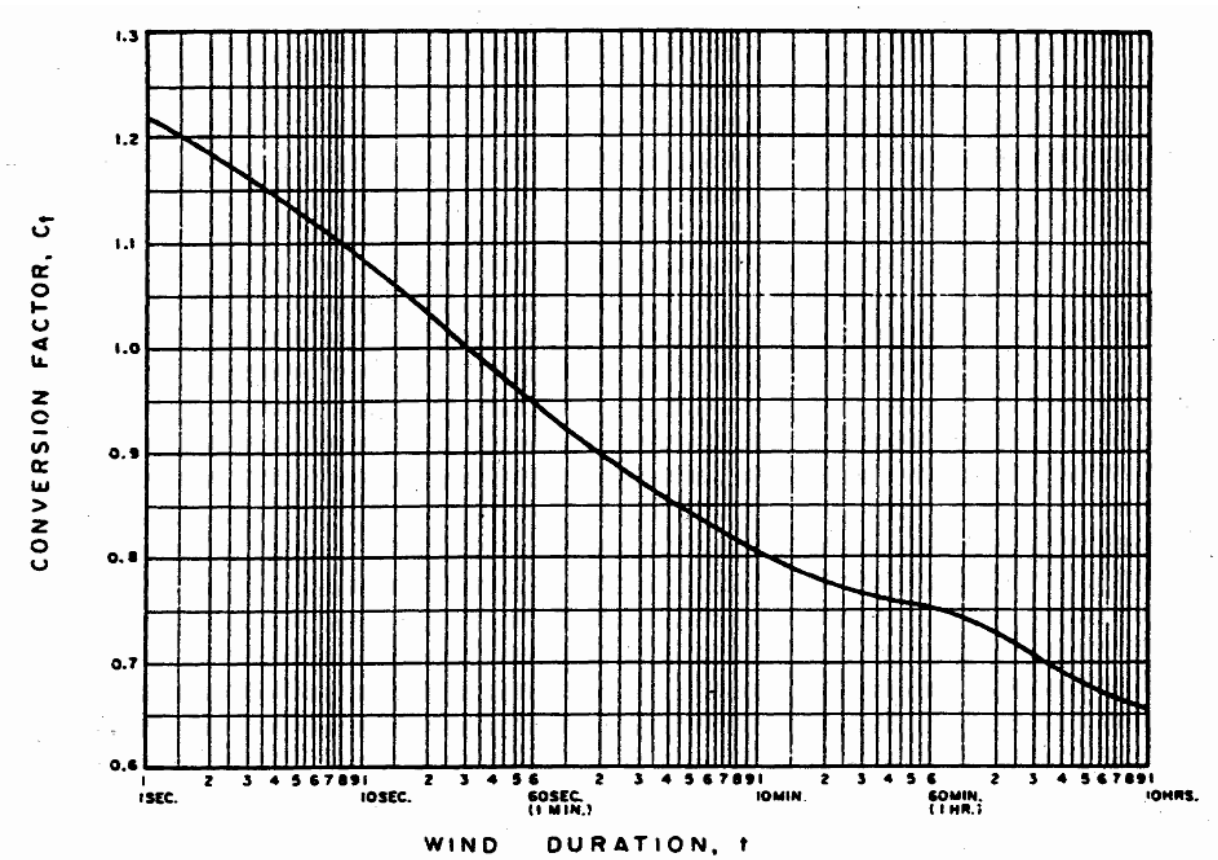

Figure 31F-3-3 Windspeed Conversion Factor [3.10]

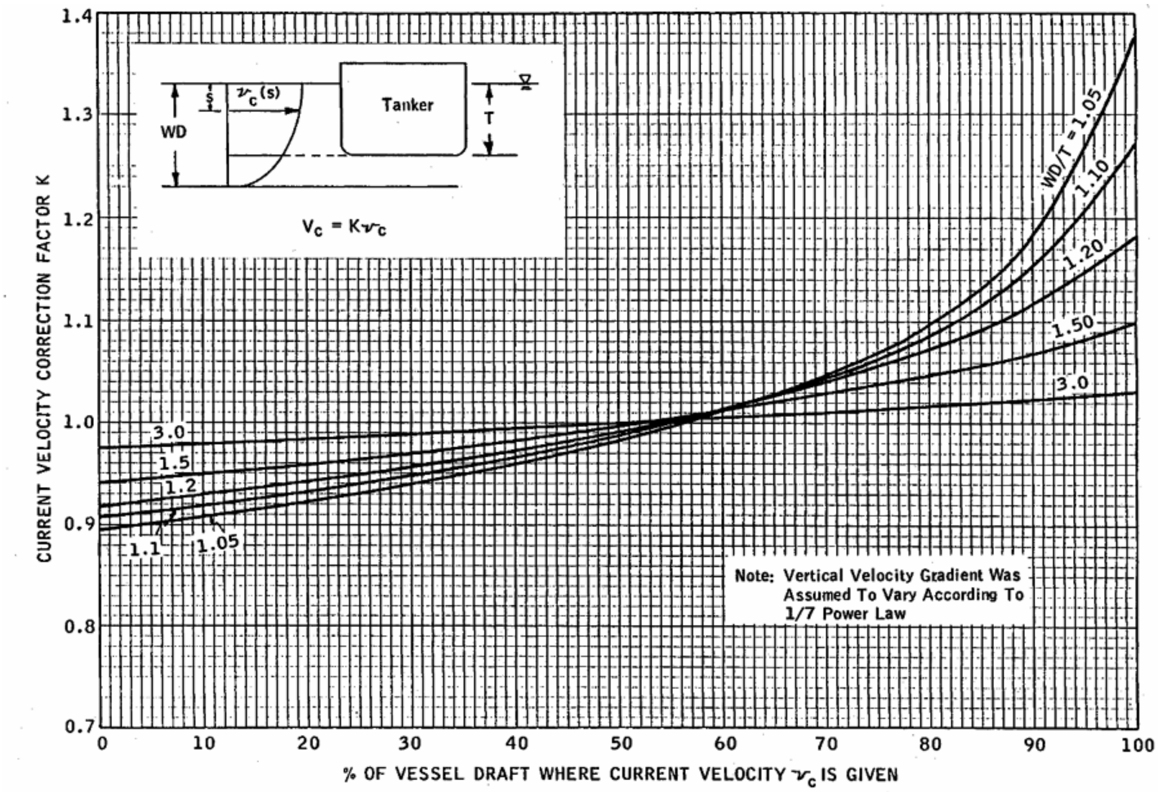

Figure 31F-3-4 Current Velocity Correction Factor (p. 41, OCIMF, 1997 [3.11])

3103F.5.2.3 Static Wind Loads on Vessels. *The "Prediction of Wind and Current Loads on VLCC's" [3.11] or the "British Standard Code of Practice for Maritime Structures" [3.12] shall be used to determine the wind loads for all tank vessels.*

Alternatively, wind loads for any type of vessel may be calculated using the guidelines in Ferritto et al, 1999 [3.13].

3103F.5.3 Current Loads. *Environmental loads induced by currents at MOTs shall be calculated as specified in this subsection.*

3103F.5.3.1 Design Current Velocity. *Maximum ebb and flood currents, annual river runoffs and controlled releases shall be considered when establishing the design current velocities for both existing and new MOTs.*

Local current velocities may be obtained from NOAA [3.14] or other sources, but must be supplemented by site-specific data, if the current velocity is higher than 1.5 knots.

Site-specific data shall be obtained by real time measurements over a one-year period. If this information is not available, a safety factor of 1.25 shall be applied to the best available data until real time measurements are obtained.

If the facility is not in operation during annual river runoffs and controlled releases, the current loads may be adjusted.

Operational dates need to be clearly stated in the definition of the terminal operating limits (see subsection 3102F.3.6).

3103F.5.3.2 Current Velocity Adjustment Factors. *An average current velocity (V_c) shall be used to compute forces and moments. If the current velocity profile is known, the average current velocity can be obtained from the following equation:*

$$V_c^2 = 1/T\int_O^T (v_c)^2\, ds \qquad (3\text{-}14)$$

where:

V_c = *average current velocity (knots)*
T = *draft of vessel*
v_c = *current velocity as a functionof depth (knots)*
s = *water depth measured from the surface*

If the velocity profile is not known, the velocity at a known water depth should be adjusted by the factors provided in Figure 31F-3-4 to obtain the equivalent average velocity over the draft of the vessel.

3103F.5.3.3 Static Current Loads. *The OCIMF [3.11], the British Standard [3.12] or the Mil-HDBK-1026/4A [3.15] procedures shall be used to determine current loads for moored tank vessels.*

3103F.5.4 Wave Loads. *When the significant wave period, T_s , is greater than 4 seconds (See subsection*

3105F.3.1), the transverse wave induced vessel reactions shall be calculated using a simplified dynamic mooring analysis described below.

The horizontal water particle accelerations shall be calculated for the various wave conditions, taken at the mid-depth of the loaded vessel draft. The water particle accelerations shall then be used to calculate the wave excitation forces to determine the static displacement of the vessel. The Froude-Krylov method discussed in Chakrabarti's Chapter 7 [3.16] may be used to calculate the wave excitation forces, by conservatively approximating the vessel as a rectangular box with dimensions similar to the actual dimensions of the vessel. The horizontal water particle accelerations shall be calculated for the various wave conditions, taken at the mid-depth of the loaded vessel draft. The computed excitation force assumes a 90- degree incidence angle with the longitudinal axis of the vessel, which will result in forces that are significantly greater than the forces that will actually act upon the vessel from quartering seas. A load reduction factor may be used to account for the design wave incidence angle from the longitudinal axis of the ship. The overall excursion of the vessel shall be determined for each of the wave conditions by calculating the dynamic response of the linear spring mass system.

3103F.5.5 Passing Vessels. *When required in subsection 3105F.3, the sway and surge forces, as well as yaw moment, on a moored vessel, due to passing vessels, shall be established considering the following:*

1. *Ratio of length of moored vessel to length of passing vessel*
2. *Distance from moored vessel to passing vessel*
3. *Ratio of mid-ship section areas of the moored and passing vessels*
4. *Underkeel clearances of the moored and passing vessels*
5. *Draft and trim of the moored vessel and draft of the passing vessel*
6. *Mooring line tensions*

The passing vessel's speed should take into consideration the ebb or flood current. Normal operating wind and current conditions can be assumed when calculating forces due to a passing vessel. Any of the following methods may be used to determine forces on a moored vessel: Wang [3.17], Flory [3.18] or Seelig [3.19].

3103F.5.6 Seiche. *The penetration of long period low amplitude waves into a harbor can result in resonant standing wave systems, when the wave forcing frequency coincides with a natural frequency of the harbor. The resonant standing waves can result in large surge motions if this frequency is close to the natural frequency of the mooring system. Subsection 3105F.3.3 prescribes the procedure for the evaluation of these effects.*

3103F.5.7 Tsunamis. *A tsunami may be generated by an earthquake or a subsea or coastal landslide, which may induce large wave heights and excessive currents. The large wave or surge and the excessive currents are potentially damaging, especially if there is a tank vessel moored alongside. Table 31F-3.8 provides estimated tsunami run-up values for specific areas of California.*

Tsunamis can be generated either by a distant or near source. A tsunami generated by a distant source (far field event) may allow operators to have an adequate warning for mitigating the risk by departing the MOT and going into deep water. For near-field events, with sources less than 500 miles away, the vessel may not have adequate time to depart.

TABLE 31F-3-8

TSUNAMI RUN-UP VALUES [ft.] in CALIFORNIA [3.20], [3.21]

Location	***100 Year Return Period***	***500 Year Return Period***
W. Carquinez Strait	*3.3*	*4.0*
Richmond Harbor Channel	*7.6*	*13.5*
Richmond Inner Harbor	*5.9*	*10.6*
Oakland Inner Harbor	*4.7-5.5*	*7.5-9.5*
Oakland Middle Harbor	*5.9*	*10.5*
Oakland Outer Harbor	*7.9-9.1*	*15.1-17.6*
Hunters Point	*3.9-5.3*	*5.0-8.7*
San Francisco – S. of Bay Bridge	*4.5-5.0*	*7.5-8.4*
Ports of Los Angeles and Long Beach	*8.0*	*15.0*
Port Hueneme	*11.0*	*21.0*

Loads from tsunami-induced waves can be calculated for various structural configurations [3.22]. Tsunami wave heights in shallow water and particle kinematics can also be obtained. Other structural considerations include uplift and debris impact.

3103F.6 Berthing Loads

3103F.6.1 General. *Berthing loads are quantified in terms of transfer of kinetic energy of the vessel into potential energy dissipated by the fender(s). The terms and equations below are based on those in Mil-HDBK-1025/1, "Piers and Wharves" [3.23]. An alternate procedure is presented in PIANC [3.24].*

Kinetic energy shall be calculated from the following equation:

$$E_{vessel} = \frac{1}{2} \cdot \frac{W}{g} \cdot V_n^{\,2} \tag{3-15}$$

where:

E_{vessel} = *Berthing energy of vessel [ft-lbs]*
W = *Total weight of vessel and cargo in pounds [long tons x 2240]*
g = *Acceleration due to gravity [32.2 ft/sec^2]*
V_n = *Berthing velocity normal to the berth [ft/sec]*

The following correction factors shall be used to modify the actual energy to be absorbed by the fender system:

$$E_{fender} = C_b \cdot C_m \cdot E_{vessel} \tag{3-16}$$

where:

E_{fender} = *Energy to be absorbed by the fender system*
C_b = *Berthing Coefficient*
C_m = *Effective mass or virtual mass coefficient (see 3103F.6.6)*

The berthing coefficient, C_b, is given by:

$$C_b = C_e \cdot C_g \cdot C_d \cdot C_c \tag{3-17}$$

where:

C_e = *Eccentricity Coefficient*
C_c = *Configuration Coefficient*
C_g = *Geometric Coefficient*
C_d = *Deformation Coefficient*

These coefficients are defined in subsections 3103F.6.2 through 3103F.6.5.

The approximate displacement of the vessel (when only partially loaded) at impact, DT, can be determined from an extension of an equation from Gaythwaite [3.25]:

$$DT = 1.25DWT\left(d_{actual}/d_{\max}\right) \tag{3-18}$$

where:

DWT = *Dead Weight Tonnage (in long tons)*
d_{actual} = *Actual arrival draft of the vessel*
d_{max} = *Maximum loaded vessel draft*

The berthing load shall be based on the fender reaction due to the kinetic berthing energy. The structural capacity shall be established based on allowable concrete, steel or timber properties in the structural components, as defined in Section 3107.

3103F.6.2 Eccentricity Coefficient (C_e). *During the berthing maneuver, when the vessel is not parallel to the berthing line (usually the wharf face), not all the kinetic energy of the vessel will be transmitted to the fenders. Due to the reaction from the fender(s), the vessel will start to rotate around the contact point, thus dissipating part of its energy. Treating the vessel as a rigid rod of negligible width in the analysis of the energy impact on the fenders leads to the equation:*

$$C_e = \frac{k^2}{a^2 + k^2} \tag{3-19}$$

where:

k = *Longitudinal radius of gyration of the vessel [ft]*
a = *Distance between the vessel's center of gravity and the point of contact on the vessel's side, projected onto the vessel's longitudinal axis [ft]*

3103F.6.3 Geometric Coefficient (C_g). *The geometric coefficient, C_g, depends upon the geometric configuration of the ship at the point of impact. It varies from 0.85 for an increasing convex curvature to 1.25 for concave curvature. Generally, 0.95 is recommended for the impact point at or beyond the quarter points of the ship, and 1.0 for broadside berthing in which contact is made along the straight side [3.23].*

3103F.6.4 Deformation Coefficient (C_d). *This accounts for the energy reduction effects due to local deformation of the ships hull and deflection of the whole ship along its longitudinal axis. The energy absorbed by the ship depends on the relative stiffness of the ship and the obstruction. The deformation coefficient varies from 0.9 for a nonresilient fender to nearly 1.0 for a flexible fender. For larger ships on energy-absorbing fender systems, little or no deformation of the ship takes place; therefore, a coefficient of 1.0 is recommended.*

3103F.6.5 Configuration Coefficient (C_c). *This factor accounts for the difference between an open pier or wharf and a solid pier or wharf. In the first case, the movements of the water surrounding the berthing vessel is not (or is hardly) affected by the berth. In the second case, the water between the berthing vessel and the structure, introduces a cushion effect that represents an extra force on the vessel away from the berth and reduces the energy to be absorbed by the fender system.*

For open berth and corners of solid piers, $C_c = 1.0$

For solid piers with parallel approach, $C_c = 0.8$

For berths with different conditions, C_c may be interpolated between these values [3.23].

3103F.6.6 Effective Mass or Virtual Mass Coefficient (C_m). *In determining the kinetic energy of a berthing vessel, the effective or the virtual mass is the sum of vessel mass and hydrodynamic mass. The hydrodynamic mass does not necessarily vary with the mass of the vessel, but is closely related to the projected area of the vessel at right angles to the direction of motion.*

Other factors, such as the form of vessel, water depth, berthing velocity, and acceleration or deceleration of the vessel, will have some effect on the hydrodynamic mass.

Taking into account both model and prototype experiments, the effective or virtual mass coefficient can be estimated as:

$$C_m = 1 + 2 \cdot \frac{d_{actual}}{B} \tag{3-20}$$

where:

d_{actual} = *Actual arrival draft of the vessel*
B = *Beam of vessel*

The value of C_m for use in design should be a minimum of 1.5 and need not exceed 2.0 [3.23].

3103F.6.7 Berthing Velocity and Angle. *The berthing velocity, V_n, is influenced by a large number of factors such as, environmental conditions of the site (wind, current, and wave), method of berthing (with or without tug boat assistance), condition of the vessel during berthing (ballast or fully laden), and human factors (experience of the tug boat captain.).*

The berthing velocity, normal to berth, shall be in accordance with Table 31F-3-9, for existing berths. Site condition is determined from Table 31F-3-10. For new berths, the berthing velocity, V_n, is established according to Table 4.2.1 of the PIANC guidelines [3.24].

Subject to Division approval, if an existing MOT can demonstrate lower velocities by velocity monitoring equipment, then such a velocity may be used.

In order to obtain the normal berthing velocity, V_n, an approach angle, defined as the angle formed by the fender line and the longitudinal axis of the vessel must be determined. The berthing angles, used to compute the normal berthing velocity, for various vessel sizes are shown in Table 31F-3-11.

TABLE 31F-3-9

BERTHING VELOCITY V_n (NORMAL TO BERTH)

Vessel Size (dwt)	Tug Boat Assistance	Site Conditions		
		Unfavorable	Moderate	Favorable
≤10,000[1]	No	1.31 ft/sec	0.98 ft/sec	0.53 ft/sec
10,000 – 50,000	Yes	0.78 ft/sec	0.66 ft/sec	0.33 ft/sec
50,000 – 100,000	Yes	0.53 ft/sec	0.39 ft/sec	0.26 ft/sec
≥100,000	Yes	0.39 ft/sec	0.33 ft/sec	0.26 ft/sec

1. If tug boat is used for vessel size smaller than 10,000 DWT the berthing velocity may be reduced by 20%

TABLE 31F- 3-10

SITE CONDITIONS

Site Conditions	Description	Wind Speed[1]	Significant Wave Height	Current Speed[2]
Unfavorable	Strong Wind Strong Currents High Waves	≥38 knots	≥6.5 ft	≥2 knots
Moderate	Strong Wind Moderate Current Moderate Waves	≥38 knots	≤6.5 ft	≤2 knots
Favorable	Moderate Wind Moderate Current Moderate Waves	≤38 knots	≤6.5 ft	≤2 knots

1. A 30-second duration measured at a height of 33 ft.
2. Taken at 0.5 x water depth

TABLE 31F-3-11 MAXIMUM BERTHING ANGLE	
Vessel Size (DWT)	***Angle [degrees]***
Barge	*15*
<10,000	*10*
10,00-50,000	*8*
> 50,000	*6*

3103F.7 Wind And Current Loads On Structures.

3103F.7.1 General. *This section provides methods to determine the wind and current loads acting on the structure directly, as opposed to forces acting on the structure from a moored vessel.*

The "vacant condition" is the case wherein there is no vessel at the berth. The "mooring and breasting condition" exists after the vessel is securely tied to the wharf. The "berthing condition" occurs as the vessel impacts the wharf, and the "earthquake condition" assumes no vessel is at the berth, and there is no wind or current forces on the structure.

The use of various load types is discussed below:

3103F.8.1 Dead Load (D). *Upper and lower bound values of dead load are applied for the vacant condition to check the maximum moment and shear with minimum axial load.*

3103F.8.2 Live Load (L). *The live load on MOTs is typically small and is therefore neglected for combinations including earthquake loads.*

3103F.8.3 Buoyancy Load (B). *Buoyancy forces shall be considered for any submerged or immersed substructures (including pipelines, sumps and structural components).*

TABLE 31F-3-12

LRFD LOAD FACTORS FOR LOAD COMBINATIONS [3.13]

Load Type	***Vacant Condition***	***Mooring & Breasting Condition***	***Berthing Condition***	***Earthquake Condition***
Dead Load (D)	*1.4^a*	*1.2*	*1.2*	*$1 \pm k^c$*
Live Load (L)	*1.7^b*	*1.7^b*		
Buoyancy (B)	*1.3*	*1.3*	*1.3*	
Wind on Structure (W)	*1.3*	*1.3*	*1.0*	
Current on Structure (C)	*1.3*	*1.3*	*1.0*	
Earth Pressure on the Structure (H)	*1.6*	*1.6*	*1.6*	*1.0*
Mooring/Breasting Load (M)		*1.3*		
Berthing Load (B_e)			*1.7*	
Earthquake Load (E)				*1.0*

a. Reduce load factor for dead load (D) to 0.9 to check components for minimum axial load and maximum moment.
b. The load factor for live load (L) may be reduced to 1.3 for the maximum outrigger float load from a truck crane.
c. k = 0.50 (PGA)

3103F.7.2 Wind Loads. *Section 6 of the ASCE 7 [3.9] shall be used to establish minimum wind loads on the structure. Additional information about wind loads may be obtained from Simiu and Scanlan [3.26].*

3103F.7.3 Current Loads. *The current forces acting on the structure may be established using the current velocities, per subsection 3103F.5.3.*

3103F.8 Load Combinations. *Each component of the structure shall be analyzed for all applicable load combinations given in Table 31F3-12 or 31F-3-13, depending on component type.*

3103F.8.4 Wind (W) and Current (C) on the Structure. *Wind and currents on the vessel are included in the mooring and breasting condition. The wind and current loads acting on the structure are therefore additional loads that can act simultaneously with the mooring, breasting and/or berthing loads.*

3103F.8.5 Earth Pressure on the Structure (H). *The soil pressure on end walls, typically concrete cut-off walls, steel sheet pile walls on wharf type structures and/or piles shall be considered.*

TABLE 31F-3-13 ***SERVICE or ASD LOAD FACTORS FOR LOAD COMBINATIONS***				
Load Type	***Vacant Condition***	***Mooring & Breasting Condition***	***Berthing Condition***	***Earthquake Condition***
Dead Load (D)	*1.0*	*1.0*	*1.0*	$1 \pm 0.7k^{a}$
Live Load (L)	*1.0*	*1.0*		
Buoyancy (B)	*1.0*	*1.0*	*1.0*	
Wind on Structure (W)	*1.0*	*1.0*	*1.0*	
Current on Structure (C)	*1.0*	*1.0*	*1.0*	
Earth Pressure on the structure (H)	*1.0*	*1.0*	*1.0*	*1.0*
Mooring/Breasting Load (M)		*1.0*		
Berthing Load (B_e)			*1.0*	
Earthquake Load (E)				*0.7*
% Allowable Stress	*100*	*100*	*100*	*133*
a. k = 0.5 (PGA)				

3103F.8.6 Mooring Line/Breasting Loads (M). *Mooring line and breasting loads can occur simultaneously or individually, depending on the combination of wind and current. Multiple load cases for operating and survival conditions may be required (see subsections 3103F.5.2 and 3105F.2). In addition, loads caused by passing vessels shall be considered for the "mooring and breasting condition". Refer to subsections 3105F.2 and 3105F.3 for the determination of mooring line and breasting loads.*

3103F.8.7 Berthing Load (B_e). *Berthing is a frequent occurrence, and shall be considered as a normal operating load. No increase in allowable stresses shall be applied for ASD, and a load factor of 1.7 shall be applied for the LRFD approach.*

3103F.8.8 Earthquake Loads (E). *In LRFD or performance based design, use a load factor of 1.0; for ASD use 0.7. A load factor of 1.0 shall be assigned to the earthquake loads. Performance based seismic analysis methodology requires that the actual force demand be limited to defined strains in concrete, steel and timber. For the deck and pile evaluation, two cases of dead load (upper and lower bound) shall be considered in combination with the seismic load.*

3103F.9 Safety Factors For Mooring Lines. *Safety factors for different material types of mooring lines are given in Table 31F-3-14. The safety factors should be applied to the minimum number of lines specified by the mooring analysis, using the highest loads calculated for the environmental conditions. The minimum breaking load (mbl) of new ropes is obtained from the certificate issued by the manufacturer. If nylon tails are used in combination with steel wire ropes, the safety factor shall be based on the weaker of the two ropes.*

3103F.10 Mooring Hardware. *Marine hardware consists of quick release hooks, other mooring fittings and base bolts. The certificate issued by the manufacturer normally defines the allowable working loads of this hardware.*

TABLE 31F-3-14 *SAFETY FACTORS FOR ROPES**	
Steel Wire Rope	*1.82*
Nylon	*2.2*
Other Synthetic	*2.0*
Polyester Tail	*2.3*
Nylon Tail	*2.5*
**From Mooring Equipment Guidelines, OCIMF[3.27]*	

3103F.10.1 Quick Release Hooks. *For new MOTs, a minimum of three quick-release hooks are required for each breasting line location for tankers larger than 50,000 DWT. At least two hooks at each location shall be provided for breasting lines for tankers less than 50,000 DWT.*

All hooks shall withstand the minimum breaking load (MBL) of the strongest line with a Safety Factor of 1.2 or greater. Only one mooring line shall be placed on each quick release hook.

3103F.10.2 Other Fittings. *Other fittings include cleats, bitts, and bollards.*

If the allowable working loads for existing fittings are not available, the values listed in Table 31F-3-15 may be used, for typical sizes, bolt patterns and layout. The allowable working loads are defined for mooring line angles up to 60 degrees from the horizontal. The combination of vertical and horizontal loads must be considered.

TABLE 31F-3-15

ALLOWABLE WORKING LOADS

Type of Fittings	*No. of Bolts*	*Bolt Size (in)*	*Working Load (kps)*
30 in. Cleat	*4*	*1-1/8*	*20*
42 in. Cleat	*6*	*1-1/8*	*40*
Low Bitt	*10*	*1-5/8*	*60 per column*
High Bitt	*10*	*1-3/4*	*75 per column*
44-1/2 in. Ht. Bollard	*4*	*1-3/4*	*70*
44-1/2 in. Ht. Bollard	*8*	*2-1/4*	*200*
48 in. Ht. Bollard	*12*	*2-3/4*	*450*

Note: This table is modified from Table 48, MIL-HDBK-1026/4A [3.15]

3103F.10.3 Base Bolts. *Base bolts are subjected to both shear and uplift. Forces on bolts shall be determined using the following factors:*

1. *Height of load application on bitts or bollards.*
2. *Actual vertical angles of mooring lines for the highest and lowest tide and vessel draft conditions, for all sizes of vessels at each particular berth*
3. *Actual horizontal angles from the mooring line configurations, for all vessel sizes and positions at each particular berth.*
4. *Simultaneous loads from more than one vessel*

For existing MOTs, the deteriorated condition of the base bolts and supporting members shall be considered in determining the capacity of the fitting.

3103F.11 Miscellaneous Loads. *Handrails and guardrails shall be designed for 25 plf with a 200 pounds minimum concentrated load in any location or direction.*

3103F.12 Symbols.

a = *Distance between the vessel's center of gravity and the point of contact on the vessel's side, projected onto the vessel's longitudinal axis [ft]*

B = *Beam of vessel*

B_1, = *Coefficient used to adjust one-second period spectral response, for the effect of viscous damping*

B_s = *Coefficient used to adjust the <u>short</u> period spectral response, for the effect of visous damping.*

C_b = *Berthing Coefficient*

C_c = *Configuration Coefficient*

C_g = *Geometric Coefficient*

C_d = *Deformation Coefficient*

C_e = *Eccentricity Coefficient*

C_m = *Effective mass or virtual mass coefficient*

C_t = *Windspeed conversion factor*

DSA = *Design Spectral Acceleration*

DSA_d = *DSA values at damping other than 5%*

DT = *Displacement of vessel*

DWT = *Dead weight tons*

d_{actual} = *Arrival maximum draft of vessel at berth*

d_{max} = *Maximum vessel draft (in open seas)*

E_{fender} = *Energy to be absorbed by the fender system*

E_{vessel} = *Berthing energy of vessel [ft-lbs]*

F_a, F_v = *Site coefficients from Tables 3-5 and 3-6*

g = *Acceleration due to gravity [32.2 ft/sec^2]*

h = *Elevation above water surface [feet]*

K = *Current velocity correction factor (Fig 3-4)*

k = *Radius of longitudinal gyration of the vessel [ft]*

PGA_X = *Peak ground acceleration corresponding to the Site Class under consideration.*

s = *Water depth measured from the surface*

S_a = *Spectral acceleration*

S_1 = *Spectral acceleration value (for the boundary of S_B and S_C) at 1.0 second*

S_A-S_F = *Site classes as defined in Table 6-1*

S_S = *Spectral acceleration value (for the boundary of S_B and S_C) at 0.2*

S_{X1} = *Spectral acceleration value at 1.0 second corresponding to the Site Class under consideration*

S_{XS} = *Spectral acceleration value at 0.2 second corresponding to the period of S_S and the Site Class under consideration*

T	=	*Draft of vessel (see Fig 3-4)*
T	=	*Period (Sec)*
T_o	=	*Period at which the constant acceleration and constant velocity regions of the design spectrum intersect*
V_c	=	*Average current velocity [knots]*
v_c	=	*Current velocity as a function of depth [knots]*
V_h	=	*Wind speed (knots) at elevation h*
V_L	=	*Over land wind speed*
V_n	=	*Berthing velocity normal to the berth [ft/sec]*
v_t	=	*Velocity over a given time period*
$V_{t=30\ sec}$	=	*Wind speed for a 30 second interval*
V_w	=	*Wind speed at 33 ft. (10 m) elevation [knots]*
W	=	*Total weight of vessel and cargo in pounds [displacement tonnage x 2240]*
WD	=	*Water Depth (Fig 3-4)*

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